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(54) **Title**: HOT-MELT INKJET PRINTING SYSTEM

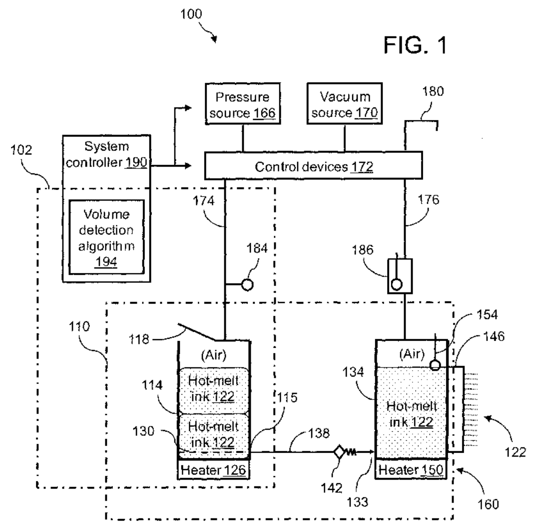


FIG. 1

(57) **Abstract**: A hot-melt inkjet printing system (100) includes a first reservoir (114) for holding hot-melt ink (122), a first reservoir heater (126) configured to heat the first reservoir, a second reservoir (134, 200) in fluid communication with the first reservoir, and a jetting assembly (146) in fluid communication with the second reservoir. The second reservoir includes a reservoir body (210), a cavity (212) defined by the reservoir body for holding hot-melt ink, and fins (214) disposed in the cavity.

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# Hot-Melt Inkjet Printing System

## TECHNICAL FIELD

[0001] This disclosure relates to hot-melt inkjet printing systems.

## BACKGROUND

[0002] Generally, in hot-melt inkjet printing systems, the supply ink is initially provided in a cold solid state, such as in the form of a solid brick. The cold solid ink may then be heated within a supply ink reservoir in order to melt the ink. Once in a hot liquid state, the hot-melt ink is maintained at elevated temperature throughout the hot-melt inkjet system to maintain the ink in a liquid state suitable for jetting. However, one of the difficulties of hot-melt inkjet systems is that air or air bubbles may accumulate in the system and may be ingested into the ink. For example, when a system is shut down and the hot-melt ink cools and becomes solid, certain inks may shrink, which tends to pull air into the system. When the system is powered up and the ink is melted, any dissolved air that was trapped in the ink when solid may remain in the system and may cause difficulty in the operation of the jets of the print head.

[0003] The presence of any air in the system is also problematic in high frequency jetting applications. For example, air bubbles may accumulate in the jetting chamber, which takes energy away from the jetting process and may eventually cause the jetting operation to fail. Consequently, a lung device is typically used to remove air from the ink prior to the ink entering a jetting chamber. To remove air from the ink is to "deaerate" the ink. This may be accomplished via air-permeable, ink-impermeable membranes within the lung device. The action of the lung device allows the ink to quickly dissolve air bubbles in ink passages. The presence of the lung device for the removal of air may be required in order to ensure fast, reliable startups, and to enable robust high frequency jetting. However, these lung devices are costly and, therefore, add expense to the overall hot-melt ink-jet printing system. Therefore, alternative approaches are needed for deaerating the ink in hot-melt inkjet printing systems and for providing more reliable and robust operation.

## SUMMARY

[0004] In one aspect, a hot-melt inkjet printing system includes a first reservoir for holding hot-melt ink, a first reservoir heater configured to heat the first reservoir, a second reservoir in fluid communication with the first reservoir, and a jetting assembly in fluid communication with the second reservoir. The second reservoir includes a reservoir body, a cavity defined by the reservoir body for holding hot-melt ink, and fins disposed in the cavity.

[0005] Implementations of this aspect of the disclosure may include one or more of the following features. In some implementations, the fins are integral with a bottom surface of the cavity of the reservoir body. The fins may be aligned substantially parallel with a longitudinal axis defined by the reservoir body. In some implementations, an operating ink level in the cavity above the fins is substantially equal to a gap distance between the fins.

[0006] The reservoir body and the fins may comprise a thermally conductive material. In some implementations, a check valve controls fluid flow in the fluid communication between the first and second reservoirs. An emersion heater, a vacuum source, and/or a pressure source may each be coupled to the first reservoir. In some examples, the hot-melt inkjet printing system includes a controller configured to monitor an ink level of the second reservoir.

[0007] In some implementations, the hot-melt inkjet printing system includes a liquid detector disposed in at least one pathway in fluid communication with one of the reservoirs for detecting liquid ink the at least one pathway. A controller may be configured to monitor the liquid detector, which in some cases is a temperature sensor. In some implementations, the hot-melt inkjet printing system includes a pressure source pneumatically coupled to the first reservoir, a vacuum source pneumatically coupled to the first reservoir, and a controller configured to monitor the liquid detector. The controller is configured to change a pressure of the at least one pathway when liquid ink is detected in the at least one pathway.

[0008] In another aspect, a method of controlling a hot-melt inkjet printing system includes monitoring an ink level sensor of a first reservoir, determining whether the ink level of the first reservoir is below a threshold level; heating a second reservoir holding hot-melt ink, and delivering melted hot-melt ink from the second reservoir to the first reservoir for replenishing the ink level of the first reservoir.

[0009] Implementations of this aspect of the disclosure may include one or more of the following features. In some implementations, the method further includes determining whether with an ink level of the replenished first reservoir is above the threshold level, discontinuing delivery of melted hot-melt ink from the second reservoir to the first reservoir, and discontinuing the heating of the second reservoir. The method may also include maintaining the ink in the first reservoir above a threshold temperature. In some examples, the first reservoir includes a reservoir body, a cavity defined by the reservoir body for holding hot-melt ink, and fins disposed in the cavity. The threshold level of the first reservoir may be a level above the fins and is substantially equal to a gap distance between the fins.

[0010] In some examples, the method includes monitoring a liquid detector disposed in a pathway in fluid communication with one of the reservoirs, determining whether liquid ink is present in the pathway, and removing the liquid ink from the pathway. Determining whether liquid ink is present in the pathway may include determining a temperature drop in the pathway. Removing the liquid ink from the pathway may include changing a pressure of the pathway.

[0011] In yet another aspect, a hot-melt inkjet printing system includes a first reservoir for holding hot-melt ink, a first reservoir heater configured to heat the first reservoir, a second reservoir in fluid communication with the first reservoir, a jetting assembly in fluid communication with the second reservoir, and a liquid detector disposed in at least one pathway in fluid communication with one of the reservoirs for detecting liquid ink in the at least one pathway.

[0012] Implementations of this aspect of the disclosure may include one or more of the following features. In some implementations, the liquid detector comprises a temperature sensor. The hot-melt inkjet printing system may also include a pressure source pneumatically coupled to the first reservoir, a vacuum source pneumatically coupled to the first reservoir, and a controller configured to monitor the liquid detector. The controller is configured to change a pressure of the at least one pathway when liquid ink is detected in the at least one pathway.

[0013] The details of one or more implementations of the disclosure are set forth in the accompanying drawings and the description below. Other aspects, features, and advantages will be apparent from the description and drawings, and from the claims.

## DESCRIPTION OF DRAWINGS

[0014] FIG. 1 is a pneumatic diagram of an exemplary hot-melt inkjet printing system with deaeration capability.

[0015] FIG. 2 is a perspective view of an exemplary rapid heating reservoir for providing deaeration within a hot-melt inkjet printing system.

[0016] FIG. 3 is a flowchart that represents exemplary operations of a hot-melt inkjet printing system.

[0017] FIG. 4 is a flow chart that represents exemplary volume detection operations of a volume detection algorithm.

[0018] FIG. 5 provides a plot, which is an example plot of the constant K for an example inkjet printing system.

[0019] FIG. 6 provides a plot, which shows a scenario in which the constant K of an inkjet printing system is not known.

[0020] FIG. 7 provides a flow chart that represents exemplary operations of detecting an ink level in a supply reservoir of an inkjet printing system.

[0021] FIG. 8 provides a flow chart that represents exemplary operations of using a melt-on-demand, two-reservoir ink delivery system in a hot-melt inkjet printing system.

[0022] FIG. 9 provides a flow chart that represents exemplary operations of detecting liquid in air or gas pathways of a hot-melt inkjet printing system.

[0023] Like reference symbols in the various drawings indicate like elements.

## DETAILED DESCRIPTION

[0024] The present disclosure provides is a hot-melt inkjet printing system with a deaeration feature. The hot-melt inkjet printing system may include (1) a melt-on-demand, two-reservoir ink delivery system for providing a rapid melt-on-demand cycle that maximizes the amount of time that the hot-melt ink in the supply reservoir is held in a cold solid state and minimizes the amount of time that the hot-melt ink is in a hot liquid state; (2) a rapid heating reservoir that includes a set of fins for efficiently delivering and transferring heat to the ink and for inhibiting ink shrinkage, which minimizes the amount of air or air bubbles that may accumulate and, therefore, helps to ensure fast, reliable startups, and to enable robust high frequency jetting; (3) a supply ink volume detector suitable for determining the ink volume regardless of its state, i.e., solid state, liquid state, and any combination thereof; (4) a liquid detector for detecting liquid in air or gas pathways of an inkjet printing system; and (5) any combinations of the melt-on-demand, two-reservoir ink delivery system; the rapid heating reservoir; the supply ink volume detector; and the liquid detector. In particular, the melt-on-demand, two-reservoir ink delivery system includes a supply reservoir and primary reservoir, wherein the primary reservoir may be the rapid heating reservoir. This combination provides improved deaeration capability that eliminates the need for a lung device, thereby simplifying and reducing the cost of the hot-melt inkjet printing system.

[0025] FIG. 1 illustrates a pneumatic diagram of an exemplary hot-melt inkjet printing system 100 with deaeration capability. The hot-melt inkjet printing system 100 includes an ink delivery system 110 capable of a rapid melt-on-demand cycle that maximizes the amount of time that the hot-melt ink in a supply reservoir 114 is held in a cold solid state and minimizes the amount of time that the hot-melt ink is in a hot liquid state. The ink delivery system 110 includes a supply reservoir 114 that has an access door 118 through which a quantity of hot-melt ink 122 may be loaded. The access door 118 has a security latch (not shown) for preventing opening while the supply reservoir 114 is under pressure, thus allowing the supply reservoir 114 to be sealed while pressurized for safety. The capacity of the supply reservoir 114 may be suitable to hold a several-hour supply of hot-melt ink 122. In some examples, the supply reservoir 114 is designed to hold between about 300 ml and about 600 ml of ink 122. A certain amount of air may be present above the hot-melt ink 122 within the supply reservoir 114.

[0026] The hot-melt ink 122 may be standard hot-melt ink provided in a cold solid state and then heated in order to transition to a hot liquid state suitable for jetting. For example, the hot-melt ink 122 may be initially installed in the supply reservoir 114 in a cold solid state, such as in the form of one or more solid bricks or pellets, as shown in FIG. 1. Subsequently, by use of a heating device 126 associated with the supply reservoir 114, a certain amount of the hot-melt ink 122 (e.g., an amount that is suitable to satisfy the primary reservoir) may be melted to a hot liquid state. In some examples, the heater 126 may be any commercially available surface heater that is thermally coupled to the supply reservoir 114, which may be formed of, for example, a thermally conductive aluminum housing. An example supplier of surface heaters is Hotwatt, Inc of Danvers, MA.

[0027] Optionally, an emersion heater 130 may be provided in place of or in combination with the heater 126. The emersion heater 130 of the ink delivery system 110 may be, for example, a custom made flat plat or flat screen emersion heater that is installed near the bottom of the supply reservoir 114 and does not contact the thermally conductive walls of the supply reservoir 114. The emersion heater 130 may be formed of a thermally conductive material that is compatible with the chemistry of the hot-melt ink 122, such as, but not limited to, stainless steel and aluminum. In some implementations, the emersion heater 130 is installed in close proximity to the bottom of the supply reservoir 114 and near its outlet. Furthermore, the emersion heater 130 in the form of a screen, which spans the entire bottom area of supply reservoir 114, may provide a filter function as well as a heating function, because the hot-melt ink 122 falls through the screen as it melts.

[0028] Alternatively, the emersion heater 130 may be a passive thermally conductive screen or plate that is coupled to the thermally conductive housing of the supply reservoir 114. Consequently, when the heater 126 is activated, heat is transferred from the thermally conductive housing of the supply reservoir 114 to the thermally conductive screen, which then transfers the heat to the hot-melt ink 122.

[0029] The heater 126 and/or, optionally, the emersion heater 130 are capable of heating the hot-melt ink 122 within the supply reservoir 114 to a temperature that is in the range of, for example, about 50° C to about 125° C. In some examples, the hot-melt ink 122 may be heated to a temperature of 125° C. Furthermore, the heater 126 and/or, optionally, the emersion heater 130 are capable of rapidly bringing the hot-melt ink 122 within the supply reservoir 114 from a cold solid state to a hot liquid state. In some examples, the heater 126 and/or optionally, the emersion heater 130 are able to bring the hot-melt ink 122 from a cold solid state to a hot liquid state in, for example, but not limited to, about 3 minutes. Again, only a certain amount of the hot-melt ink 122 (e.g., an amount suitable to satisfy the primary reservoir 134) may be melted to a hot liquid state.

[0030] An outlet 115 of the supply reservoir 114, which may exit near the bottom of the vessel, feeds an inlet 133 of a rapid heating reservoir 134 of the ink delivery system 110 via a fluid line 138. The rapid heating reservoir 134 is the primary reservoir of hot-melt inkjet printing system 100. Installed in the flow of the fluid line 138 and upstream of the rapid heating reservoir 134 is a check valve 142, which may be any commercially available check valve. In some examples, the check valve 142 may be a spring-loaded check valve that is spring-loaded shut to about 2 pounds per square inch (PSI). The rapid heating reservoir 134 may be a vacuum/pressure chamber for holding a quantity of hot-melt ink 122 that is supplied from the supply reservoir 114. The hot-melt ink 122 from the rapid heating reservoir 134 supplies a jetting assembly 146. In some examples, the rapid heating reservoir 134 is designed to hold between about 12 ml and about 16 ml of ink. In some implementations, a certain amount of air is present above the hot-melt ink 122 within the rapid heating reservoir 134.

[0031] In some implementations, the rapid heating reservoir 134 is suitable for use as, for example, the primary reservoir of an inkjet printing system and is configured to enable fast system startups and improved system performance and reliability. The rapid heating reservoir 134 may include a set of fins for efficiently delivering and transferring heat to the ink and for inhibiting ink shrinkage, which minimizes the amount of air or air bubbles that may accumulate and, therefore, helps to ensure fast, reliable startups, and to enable robust high frequency jetting. The rapid heating reservoir 134, in some examples, avoids entirely, air accumulation therein when cycling the ink between liquid hot state and solid cold state.

[0032] In some implementations, a heater 150 is associated with the rapid heating reservoir 134. The heater 150 is used to maintain the hot-melt ink 122 in a hot liquid state that is suitable for jetting via the jetting assembly 146. The heater 150 may be any commercially available surface heater, such as a surface heater from Hotwatt, Inc of Danvers, MA, that is thermally coupled to the rapid heating reservoir 134, which may be formed of, for example, a thermally conductive aluminum housing. The heater 150 is capable of maintaining the hot-melt ink 122 within the rapid heating reservoir 134 at a temperature that is in the range of, for example, between about 120° C and about 130° C. In some examples, the hot-melt ink 122 is maintained at a temperature of 125° C.

[0033] A primary ink sensor 154 may be installed within the rapid heating reservoir 134 for detecting the level (L) of the hot-melt ink 122 therein. The primary ink sensor 154 may be any commercially available float-type or thermistor-type sensor, such as the level sensors supplied by Honeywell Sensing and Control of Golden Valley, MN. The primary ink sensor 154 is used for monitoring the level of the hot-melt ink 122 within the rapid heating reservoir 134. When the primary ink sensor 154 detects that the ink level in the rapid heating reservoir 134 is low, a rapid melt-on-demand cycle is initiated at the supply reservoir 114 for melting the hot-melt ink 122, which may be in a cold solid state, into a hot liquid state and replenishing the rapid heating reservoir 134 with liquid hot-melt ink 122. In some examples, a certain amount of air is present above the hot-melt ink 122 within the rapid heating reservoir 134.

[0034] The rapid heating reservoir 134 is fluidly coupled to the jetting assembly 146, which has a plurality of orifices (not shown) oriented toward a target print media (not shown). The jetting assembly 146 is typically the mechanism of an inkjet printer by which tiny streams of hot-melt ink 122 are jetted onto the target print media, such as onto a piece of paper, onto a product package (e.g., a box or bag), onto a continuous-feed substrate for making product packaging, and so on.

[0035] The hot-melt inkjet printing system 100 may include a pressure source 166, such as any commercially available pump, and a vacuum source 170, such as any commercially available vacuum pump, that are pneumatically coupled to the supply reservoir 114, the rapid heating reservoir 134, and the jetting assembly 146 via, for example, an arrangement of control devices 172 for controlling the pressure and vacuum functions of the hot-melt inkjet printing system 100. A vacuum/pressure line 174 feeds the supply reservoir 114 and a vacuum/pressure line 176 feeds the rapid heating reservoir 134. The control devices 172 may include any standard control devices typically found in inkjet systems, such as, but not limited to, flow valves, check valves, pressure sensors, vacuum sensors, accumulators, restrictors, filters, and any combinations thereof. Additionally, a vent 180 is included for providing a path to atmosphere. Normal atmospheric pressure is defined as 1 atmosphere (atm), which equates to about 14.7 PSI. The vent 180 may be, for example, a restrictor device that has an orifice exiting to atmosphere and, in some examples, produces about 6.3 PSI of pressure.

[0036] A pressure sensor 184 is connected to the vacuum/pressure line 174 that feeds the supply reservoir 114. The pressure sensor 184 may be used to monitor the pressure at the supply reservoir 114 at any given time. The pressure sensor 184 may be any commercially available pressure sensor, such as those supplied by Honeywell Sensing and Control.

[0037] Additionally, the hot-melt inkjet printing system 100 may include a liquid detector 186, e.g., a flood ink sensor 186, installed in the flow of the vacuum/pressure line 176 of the rapid heating reservoir 134. The flood ink sensor 186 is an example of a liquid detector 186 in an air or gas pathway, such as in the vacuum/pressure line 176 of the rapid heating reservoir 134. The flood ink sensor 186 may be, for example, a thermistor-type sensor that is normally hot in free space and cools when in contact with ink. The temperature sensitivity of the flood ink sensor 186 may be within a range that is suitable for a hot-melt system, which may be operating, for example, at about 125° C. In some examples, the flood ink sensor 186 of this temperature range may be a sensor that is supplied by Fujifilm Dimatix, Inc. of Lebanon, NH.

[0038] When cooling is sensed by the liquid detector 186 due to the hot-melt ink 122 being present in the vacuum/pressure line 176, the vacuum source 170 may be automatically deactivated and/or the pressure source 166 may be automatically activated, which supplies positive pressure to clear the vacuum/pressure line 176. The use of a flood ink sensor is not limited to the primary reservoir only of an inkjet printing system. A flood ink sensor may be used with any reservoir in the system that has air above the ink, such as with the supply reservoir of an inkjet printing system. Furthermore, the liquid detector 186, such as flood ink sensor, may be applicable to other processes that may benefit from protection against liquids entering air or gas pathways.

[0039] Furthermore, in some implementations, the hot-melt inkjet printing system 100 includes a system controller 190 that provides the overall control of the hot-melt inkjet printing system 100 and is, therefore, in communication with all active components thereof. In particular, the system controller 190 monitors feedback from, for example, the primary ink sensor 154 to initiate the rapid melt-on-demand cycle at the supply reservoir 114 as needed, the pressure sensor 184 during a supply ink volume detection operation, and the flood ink sensor 186 to detect any liquid, such as hot-melt ink 122, in vacuum/pressure line 176.

[0040] The system controller 190 may execute a volume detection algorithm 194 for determining the volume of hot-melt ink 122 in the supply reservoir 114. The volume of ink 122 (i.e., supply ink volume) plus the volume of air above the ink 122 (i.e., air-above-ink volume) equals the total fixed capacity of the supply reservoir 114 (i.e., reservoir volume), where the supply ink volume and the air-above-ink volume are variable and the reservoir volume is fixed.

[0041] FIG. 2 illustrates a perspective view of an exemplary rapid heating reservoir 200 for providing deaeration capability within the hot-melt inkjet printing system 100. The rapid heating reservoir 200 includes a reservoir body 210. A cavity 212 within the reservoir body 210 forms a well 212 for holding a quantity of hot-melt ink 122. Integrated into the reservoir body 210 at the bottom surface 213 of the well 212 is a set of fins 214 that may be arranged substantially in parallel with a longitudinal axis 205 of the well 212 and/or reservoir body 210. A fluid channel 216 is provided through a side wall of the reservoir body 210 for supplying ink in liquid form to the well 212. The rapid heating reservoir 200 further includes a mounting bracket 218 (e.g., bar) for providing a mechanical and/or fluid attachment to the jetting assembly 146. An outlet (not shown) of the rapid heating reservoir 200 is fluidly connected to the jetting assembly 146. FIG. 2 also shows a set of electrical connections 220 associated with the jetting assembly 146. The set of electrical connections 220 may run along the side of the reservoir body 210 of the rapid heating reservoir 200. A variety of holes or openings may be defined by the reservoir body 210 for accommodating various mechanical and/or fluid coupling, such as for fastening a cover (not shown) atop the reservoir body 210, for installing the rapid heating reservoir 200 within the hot-melt inkjet printing system 100, for connecting the rapid heating reservoir 200 to other components (e.g., supply reservoir 114, heater 150, primary ink sensor 154, and control devices 172) of the hot-melt inkjet printing system 100, and/or for making any pressure, vacuum, and/or fluid connection thereto.

[0042] The reservoir body 210 may be formed of a material that is thermally conductive and compatible with the chemistry of the ink formulations. For example, the reservoir body 210 may be formed of aluminum or stainless steel. A surface heater, such as heater 150, may be in contact with the outer surface of one or more walls of the reservoir body 210. Because the reservoir body 210 and the fins 214 are highly thermally conductive, heat may be transferred rapidly from, for example, the surface heater 150, through the material of the reservoir body 210 and the fins 214 to the hot-melt ink 122 therein. The presence of fins 214 provides more surface area that is in contact with the hot-melt ink 122, as compared with an ink reservoir without fins. As a result, the transfer of heat from the reservoir body 210 and the fins 214 to the hot-melt ink 122 is enhanced.

[0043] The rapid heating characteristics of the rapid heating reservoir 134 may be dependent on (1) the distance that heat must travel through the low diffusivity ink and (2) how fast high diffusivity aluminum walls can be brought up to temperature, which is dependent on how much thermal energy can be supplied by, for example, the heater 150. A conventional primary reservoir must transfer the heat from the outer surfaces of a block and then through the full volume of ink in order to melt the ink. However, the finned rapid heating reservoir 200 creates more heating surface and a short distance between the fins 214 for heat to travel across the ink, thereby allowing rapid heating of the ink between the fins 214. Furthermore, when in use, the ink level F above the fins 214 may be controlled to a level that is about equal to the size of a gap G between the fins 214. In this way, a short distance is also provided for heat to travel from the top surface of the fins 214 to the top surface of the ink, thereby allowing rapid heating from the top of the fins 214 to the top surface of the ink

[0044] One of the difficulties of hot-melt inkjet systems is that air or air bubbles may accumulate in the system and may be ingested into the ink. For example, air bubbles may accumulate in the jetting chamber, which takes energy away from the jetting process, which may eventually cause the jetting operation to fail. For example, when hot-melt ink within a reservoir cools from a liquid hot state to a solid cold state, it may shrink in volume by, for example, about 10% (e.g., shrink in length, width, and height), depending on the cooling rate. This ink shrinkage can leave a gap between the solid ink and the reservoir walls, thereby exposing more of the surface area of the ink and allowing air to diffuse into the ink.

[0045] The presence of multiple fins 214 serves to inhibit the ink shrinkage, because the presence of multiple fins 214 essentially creates multiple small reservoirs instead of one large reservoir. When the ink 122 is allowed to cool and solidify, the top of the fins 214 exert a force that causes the ink to adhere to the inner walls of the well 212, even in the top of the well 212 where no fins are present, which prevents air from entering the ink around the edges. Additionally, the ink around the outside of the well 212 adheres to the walls upon cooling, which also prevents air from entering the ink around the edges. Therefore, the presence of fins 214 serves to inhibit the ink shrinkage. Consequently, the rapid heating reservoir 200 minimizes the amount of air or air bubbles that may accumulate within the rapid heating reservoir 134 when cycling the ink between the liquid hot state and the solid cold state. Because the ink tends to stay in contact with the surfaces of the small reservoirs that are created by the fins 212, the amount of air diffusing into the ink is reduced and/or eliminated. Furthermore, when the ink is heated and it expands, there are substantially no air bubbles at the walls to be diffused into the ink.

[0046] The specific heat of aluminum is low compared with the specific heat of the ink and the diffusivity of aluminum is much greater than the diffusivity of the ink. Consequently, the heat transfers rapidly through the aluminum and the heat is then transported rapidly from the aluminum throughout the ink. Therefore, an advantage of the rapid heating reservoir is that it allows a rapid heating and cooling cycle because it takes less time to heat and cool small reservoirs, as compared to the time it takes to heat and cool one large reservoir. As a result, the rapid heating reservoir 200 helps to ensure fast, reliable startups, and to enable robust high frequency jetting.

[0047] Referring to FIG. 3, a flow chart 300 represents an arrangement of operations for operation of the hot-melt inkjet printing system 100. Operations include loading 302 one or more blocks of hot-melt ink 122 (i.e., in cold solid state) into the supply reservoir 114 via the access door 118, and sealing 304 the supply reservoir 114 (e.g., locking the access door 118) for pressurization. Operations further include, for example under the control of the system controller 190, activating 306 the heaters 126, 150, and, optionally, the emersion heater 130, to melt the hot-melt ink 122 in the supply reservoir 114, which results in at least a portion of the hot-melt ink 122 transitioning from a cold solid state to a hot liquid state. Operations include pressurizing 308 (e.g., to about 6 PSI of pressure) the supply reservoir 114 (e.g., via the pressure source 166 and vacuum/pressure line 174 ) to pump a quantity of liquid hot-melt ink 122 from the supply reservoir 114 through the fluid line 138 and into the rapid heating reservoir 134, where the liquid hot-melt ink 122 is maintained at an elevated temperature. This pressure is sufficiently strong to open the check valve 142. Operations further include detecting 310 (e.g., via the primary ink sensor 154) a threshold level of hot-melt ink 122 within primary reservoir 134 sufficient for operation of the hot-melt inkjet printing system 100. Upon detecting the threshold level of hot-melt ink 122, operations include suspending 312 the ink cycle and closing 314 the check valve 142. Additionally, once the initial ink cycle is suspended, the heater 126 and, optionally, the emersion heater 130 are deactivated and the hot-melt ink 122 within the supply reservoir 114 is allowed to cool and may begin to solidify. Operations further include applying 316 a vacuum to the primary reservoir 134 (e.g., via vacuum source 170 and vacuum/pressure line 176) and jetting 218 onto print media (e.g., via the jetting assembly 146). Throughout the operations of the hot-melt inkjet printing system 100, the operations of the control devices 172 are appropriately managed according to the functions of the jetting process.

[0048] Periodically, normal inkjet printing operations may be interrupted and a jetting assembly purge operation may occur. In this case, by use of the pressure source 166 and the control devices 172, pressure, instead of a vacuum, is applied to the rapid heating reservoir 134 and the jetting assembly 146. The check valve 142 prevents back flow into the supply reservoir 114 while purging. The pressure on the rapid heating reservoir 134 and the jetting assembly 146 pushes a quantity of hot-melt ink 122 through the orifices (not shown) of the jetting assembly 146, in order to clear any blocked or clogged orifices.

[0049] Throughout the normal inkjet printing operations and purge operations of the hot-melt inkjet printing system 100, the system controller 190 continuously monitors feedback from the primary ink sensor 154 to initiate the rapid melt-on-demand cycle at the supply reservoir 114 as needed. As long as the primary ink sensor 154 senses an adequate ink level at the rapid heating reservoir 134, no action is taken. However, in the event that the primary ink sensor 154 senses a low ink level at the rapid heating reservoir 134, the system controller 190 initiates a rapid melt-on-demand cycle at the supply reservoir 114.

[0050] The heater 126 and, optionally, the emersion heater 130 of the supply reservoir 114 are activated in order to rapidly melt the hot-melt ink 122 in the supply reservoir 114, which results in hot-melt ink 122 rapidly transitioning from a partially or entirely cold solid state to a partially or entirely hot liquid state. The heating cycle time may depend on, for example, the amount of area of the heater 126 that is in contact with the hot-melt ink 122 and the wattage of the heater 126. Again, only a certain amount of hot-melt ink 122 (e.g., an amount suitable to satisfy the rapid heating reservoir 134) needs to be heated during the melt-on-demand cycle. The entire quantity of hot-melt ink 122 does not need to be melted. Optionally, the supply reservoir 114 may be held at a higher temperature than room temperature, with the hot-melt ink 122 still solid, if a faster response is needed.

[0051] Pressure (e.g., about 6 PSI of pressure) is then applied to the supply reservoir 114 (e.g., via the pressure source 166 and the vacuum/pressure line 174) to pump a quantity of the liquid hot-melt ink 122 from the supply reservoir 114 through the fluid line 138 and into the rapid heating reservoir 134, where the liquid hot-melt ink 122 is maintained at an elevated temperature. When the primary ink sensor 154 detects that the level of hot-melt ink 122 within the rapid heating reservoir 134 is sufficient for operation, the melt-on-demand cycle is suspended, i.e., the heater 126 and, optionally, the emersion heater 130 of the supply reservoir 114 are deactivated and pressure is suspended, which allows the hot-melt ink 122 to begin cooling. Preferably, the entire melt-on-demand cycle may take a few minutes only, such as about 10 minutes or less.

[0052] Additionally, the entire quantity of hot-melt ink 122 in the supply reservoir 114 need not be melted before pumping begins. As long as a sufficient quantity of liquid hot-melt ink 122 is present at the outlet 115 of the supply reservoir 114, pumping may begin. Therefore, depending on the quantity of hot-melt ink 122 in the supply reservoir 114, it is possible that the entire quantity of hot-melt ink 122 may not fully melt during the time that it takes to complete the melt-on-demand cycle. Furthermore, the amount of solidification that takes place in the supply reservoir 114 between melt-on-demand cycles may depend on the amount of ink in the supply reservoir 114 and the amount of time between the melt-on-demand cycles, which may depend on the ink usage of the hot-melt inkjet printing system 100. Consequently, the hot-melt ink 122 may be fully solid or partially solid and partially liquid at the beginning of any given melt-on-demand cycle.

[0053] During normal inkjet printing operations of the hot-melt inkjet printing system 100, the heater 150 may be continuously activated. The hot-melt ink 122 is fed into the well 212 of the rapid heating reservoir 200 via the fluid channel 216 and maintained in a liquid hot state within the rapid heating reservoir 200. Heat is transferred from the heater 150 through the walls of the reservoir body 210 and the fins 214, which are in contact with the ink 122, and the heat energy is, thus, absorbed into the ink 122. The level of ink 122 above the fins 214 may be controlled to a level that is about equal to the gap between the fins 214. As a result, the heat is transferred from the fins 214 across a short distance through the ink 122 between the fins 214 and across a short distance through the ink 122 from the top surface of the fins 214 to the top surface of the ink 122.

[0054] Alternatively, the hot-melt inkjet printing system 100 may be shut down for any reason and the hot-melt ink 122 within the system, including within the rapid heating reservoir 200, may be allowed to cool to a solid cold state. In this case, the amount of shrinkage of hot-melt ink 122 is minimized because of the presence of the fins 214 within the rapid heating reservoir 200, thereby minimizing, or entirely avoiding, air accumulation within the well 212 for improving system performance and reliability.

[0055] Subsequently, a system startup cycle may be initiated, wherein any heaters, such as heater 126 and heater 150, are activated in order to transition the hot-melt ink 122 from a solid cold state to a liquid hot state. In this case, because of the presence of the fins 214 within the rapid heating reservoir 200, which provide short distances only across which heat is transferred through the ink 122, the startup cycle may be completed in a relatively shortened amount of time compared with reservoirs without fins. In some examples, the length of the startup cycle may be about 10 minutes or less. As a result, the action of the ink delivery system 110 that includes, for example, the rapid heating reservoir 200 helps to ensure fast, reliable startups, and to enable robust high frequency jetting.

[0056] In some examples, the presence of the rapid heating reservoir 200 within the hot-melt inkjet printing system 100 reduces, or preferably entirely eliminates, startup problems and the need for a lung device up to an operating frequency of, for example, about 18 kilohertz (kHz). Furthermore, in certain printing situations, the presence of the rapid heating reservoir 200 may increase the operating frequency of existing hot-melt inkjet printing systems.

[0057] In an alternative higher frequency implementation, the hot-melt inkjet printing system 100 may include the combination of the rapid heating reservoir 200 and a lung device to achieve a yet higher operating frequency, such as operating frequencies above about 22 kHz. Referring again to FIG. 1, in this implementation the lung device (not shown) may be inserted, for example, between the rapid heating reservoir 134 and the jetting assembly 146.

[0058] Referring to again to FIG. 1, in some implementations, the hot-melt inkjet printing system 100 includes an ink volume detector 102 for detecting the ink volume in the supply reservoir 114 without the use of internal sensing devices, such as float-type or thermistor-type sensors, which generally require that the ink be in liquid state. In some examples, the ink volume detector 102 includes an external pressure sensor 184 for monitoring the pressure in the pressurized supply reservoir 114. The ink volume detector 102 may execute a volume detection algorithm 194 for determining the ink volume in the supply reservoir 114. As a result, the ink volume detector 102 may be used for determining the ink volume regardless of its state, i.e., solid state, liquid state, and any combination thereof. In cases where the ink is in a solid state, the volume may be determined regardless of its shape. As a result, the ink volume detector 102 may be used in both a hot-melt inkjet printing system and a liquid inkjet printing system. Implementations of the ink volume detector 102 are disclosed in a concurrently filed application, entitled "Apparatus For And Method Of Supply Ink Volume Detection In An Inkjet Printing System," the entire contents of this application is hereby incorporated by reference in its entirety.

[0059] The ink volume detector 102 is independent of the ink type (e.g., hot-melt or liquid) and of the ink state (e.g., solid, liquid, or partially solid and partially liquid). Both hot-melt and liquid ink types of systems can provide a pressurized supply reservoir 114 in combination with an external pressure sensor 184 for monitoring the pressure therein, and a volume detection algorithm 194 for determining the ink volume in the supply reservoir 114. Periodically during the continuous operation of the hot-melt inkjet printing system 100, the supply ink volume is determined by use of the ink volume detector 102 to determine when hot-melt ink 122 in the supply reservoir 114 needs to be replenished. Under the control of the volume detection algorithm 194, a supply ink volume detection operation may occur that uses the pressure source 166 and the pressure sensor 184. If the supply ink volume is above a threshold supply level, no action is required. However, if the supply ink volume is below the threshold supply level, the volume detection algorithm 194 and/or the system controller 190 prompts an operator or user to replenish the hot-melt ink 122 of the supply reservoir 114 and/or the liquid ink 314 in the supply reservoir 310.

[0060] The system controller 190 executes the volume detection algorithm 194 to determine whether the supply ink volume is above threshold supply level. In some implementations, the volume detection algorithm 194 includes the relationship that the volume of supply ink 122 in the supply reservoir 114 plus the volume of air above the ink 122 in the supply reservoir 114 equals the total fixed volume of the supply reservoir 114, where the supply ink volume and the air-above-ink volume are variable and the reservoir volume is fixed.

[0061] Referring to FIG. 4, a flow chart 400 represents an arrangement of volume detection operations of the volume detection algorithm 194. Typically, the volume detection operations are executed on the system controller 190, and include:

1. Prompting 402 activation/deactivation of the pressure source (e.g., pressure source 166) in order to control the pressure of the supply reservoir 114;
2. Monitoring 404 feedback from active components. In particular, monitoring feedback from the supply pressure sensor 184;
3. Measuring 406 the transition time between two pressure points at the supply reservoir by monitoring the supply pressure sensor;
4. Determining 408 a relationship of air-above-ink volume vs. time to pressurize for a certain combination of system components, such as for a supply reservoir, a pressure source that outputs a flow through an orifice, and pressure control devices. The air-above-ink volume vs. time to pressurize relationship is heretofore referred to as K, which is substantially constant and unique for each certain combination of system components;
5. Determining 410 the ink supply ink volume in the supply reservoir; and
6. Prompting 412 action to replenish the supply ink in the supply reservoir when it is determined that a low level condition is present.

[0062] In some implementations of the volume detection algorithm 194, (1) the constant K is determined for a certain system that contains a supply reservoir that has a known reservoir volume $V_r$, which then allows (2) the air-above-ink volume $V_a$ to be determined, which then allows (3) the unknown reservoir ink volume $V_x$ to be determined. These determinations may be accomplished according to the following calculations.

[0063] Constant K calculation:

K for a supply reservoir = $V_r/t_r$, where (Equation 1)

$V_r$ = Empty reservoir volume;

$t_r$ = Time to transition an empty supply reservoir from, for example, about 0 PSI to about 1.2 PSI;

where volume is in milliliters and time is in seconds (sec).

[0064] FIG. 5 illustrates an exemplary plot 500 of the constant K for an example inkjet printing system. An empty supply reservoir of the example inkjet printing system has a volume $V_r$ of about 600 ml and a time $t_r$ to transition from about 0 PSI to about 1.2 PSI of about 6 sec. Therefore, a substantially linear curve 510 of plot 500 has a slope of K = $V_r/t_r$, which is 600 ml/6 sec or K = about 100 ml/sec.

[0065] In the case of a supply reservoir that contains an unknown volume of ink, as opposed to an empty supply reservoir, the unknown reservoir ink volume $V_x$ may be expressed as follows.

[0066] Unknown reservoir ink volume $V_x$ calculation:

$V_x = V_r - V_a$, where (Equation 2)

$V_x$ = Unknown reservoir ink volume;

$V_r$ = Empty reservoir volume; and

$V_a$ = Air-above-ink volume.

where volume is in milliliters and time is in seconds.

[0067] Once the value of K is determined, Equations 3 and 4 may be applied as follows in order to determine the unknown reservoir ink volume $V_x$ of the supply reservoir that is not empty. The unknown reservoir ink volume $V_x$ may be determined by measuring the time $t_x$ that it takes to transition the supply reservoir having an unknown ink volume from, for example, about 0 PSI to about 1.2 PSI. Therefore, when the value of K is known

[0068] Air-above-ink volume $V_a$ calculation when K is known:

$V_a = K*t_x$, where (Equation 3)

$t_x$ = Time it takes to transition the supply reservoir having an unknown ink volume from, for example, about 0 PSI to about 1.2 PSI.

then substituting Equation 3 into Equation 2,

$V_x = V_r-(K*t_x)$ (Equation 4)

[0069] Continuing the example of FIG. 5, for $V_r$=600 ml, K=100 ml/sec, and if it takes, for example, 2.6 sec to transition the supply reservoir having an unknown ink volume from, for example, about 0 PSI to about 1.2 PSI, then $t_x$= 2.6 sec; then in this example,

$V_x$ = 600 ml - (100 ml/sec x 2.6 sec) = about 340 ml.

[0070] FIG. 6 illustrates plot 600, which shows a scenario in which the constant K of a certain inkjet printing system is not known. In this example, the empty reservoir volume $V_r$ is known, but the constant K must first be determined in order to then determine the unknown reservoir ink volume $V_x$. The empty reservoir volume $V_r$ may be, for example, 600 ml.

[0071] Constant K calculation:

$K = V_i/(t_x - t_i)$, where (Equation 5)

$V_i$ = Known volume of ink added to reservoir (e.g., ~150 ml);

$t_x$ = Time it takes to transition the supply reservoir having an unknown ink volume from, for example, about 0 PSI to about 1.2 PSI; and

$t_i$ = Time to transition a supply reservoir from, for example, about 0 PSI to about 1.2 PSI with known volume of ink $V_i$ (e.g., ~150 ml) added to reservoir added to reservoir;

where volume is in milliliters and time is in seconds.

[0072] For example, if $V_i$ = 150 ml, and if it takes about 2.6 sec to transition the supply reservoir having an unknown ink volume from about 0 PSI to about 1.2 PSI, then $t_x$= 2.6 sec; and if it takes about 1.1 sec to transition a supply reservoir from about 0 PSI to about 1.2 PSI with a known volume of ink $V_i$ (e.g., ~150 ml) added to the reservoir, then $t_i$= 1.1 sec.

[0073] Therefore in this example, K = 150 ml/(2.6 sec-1.1 sec) = 150 ml/1.5 sec = 100 ml/sec. Referring again to FIG. 6, a substantially linear curve 610 of plot 600 has a slope of $K = V_i/(t_x - t_i)$, which is about 100 ml/sec.

[0074] The volume $V_i$ of ink that is added may be any volume as long as it is known and as long as it is large enough to produce an accurate result. Once the value of K is determined, Equations 2, 3, and 4 may be applied as follows in order to determine the unknown reservoir ink volume $V_x$.

[0075] For some inkjet printing systems, the K value whether determined by Equation 1 or by Equation 5 should be substantially the same (e.g., the examples shown in FIGS. 5 and 6).

[0076] Unknown reservoir ink volume $V_x$ calculation:

$V_x = V_r - V_a$, where (Equation 2)

$V_x$ = Unknown reservoir ink volume;

$V_r$ = Empty reservoir volume; and

$V_a$ = Air-above-ink volume.

where volume is in milliliters and time is in seconds.

[0077] Air-above-ink volume $V_a$ calculation when K is known:

$V_a = K*t_x$, where (Equation 3)

$t_x$ = Time it takes to transition the supply reservoir having an unknown ink volume from, for example, about 0 PSI to about 1.2 PSI.

then substituting Equation 3 into Equation 2,

$V_x = V_r-(K*t_x)$ (Equation 4)

[0078] Continuing the example of FIG. 6, for $V_r$=600 ml, K=100 ml/sec, and if it takes, for example, 2.6 sec to transition the supply reservoir having an unknown ink volume from about 0 PSI to about 1.2 PSI, then $t_x$= 2.6 sec; then in this example,

$V_x$ = 600 ml - (100 ml/sec x 2.6 sec) = about 340 ml.

[0079] In Equations 1 and 5, the constant K is based on a pump (e.g., pressure source 166) outputting a constant flow through an orifice (e.g., vent 180) to the supply reservoir volume. Therefore, the time $t_x$ that it takes to reach, for example, about 1.2 PSI from about 0 PSI is directly proportional to the air-above-ink volume $V_a$ and inversely proportional to the unknown reservoir ink volume $V_x$.

[0080] Alternatively, for a system that is already installed in the field, rather than adding a known volume of ink and using equations 2, 3, 4, and 5, as illustrated in FIG. 6, the supply reservoir may be emptied and then equations 1, 2, 3, and 4 may be used, as illustrated in FIG. 5, to determine the unknown reservoir ink volume $V_x$.

[0081] FIG. 7 a flow chart 700 represents an arrangement of operations for detecting the ink level in the supply reservoir of an inkjet printing system. The operations are suitable for use with either a hot-melt inkjet printing system, such as the exemplary hot-melt inkjet printing system 100 shown in FIG. 1. Operations include initiating 710 the ink volume detection operation, for example, by the system controller 190. Optionally, the ink volume detection operation may be initiated manually by an operator of the inkjet printing system. The frequency of the ink volume detection operation may depend on certain criteria, such as, but not limited to, a threshold time interval, a threshold number of "primary ink cycles," and any combination thereof. Operations further include determining 712 whether the K value is known for a certain inkjet system with its unique set of components. For example, the volume detection algorithm 194 may query a data storage device (not shown) of the system controller 190 for a value of the constant K, which may be a value stored in ml/sec. The data storage device may be, for example, a register or a memory device that has read and write capability. If a K value is found, the K value is read into the volume detection algorithm 194, the operations proceed to operation 720. If a K value is not found, the operations proceed to determining 714 whether the supply reservoir 114 is empty or substantially empty of ink.

[0082] If the supply reservoir is empty, operations proceed to operation 716. If the supply reservoir is not empty, operations proceed to operation 718. Operations may include determining 716 the value of K using the empty supply reservoir according to Equation 1, which is: $K = V_r/t_r$. The empty reservoir volume $V_r$ is known (e.g., provided by the manufacturer of the reservoir). Additionally, the time $t_r$ to transition an empty supply reservoir from one pressure value to another pressure value is known (e.g., provided by the manufacturer of the reservoir). Optionally, the time $t_r$ may be determined by the volume detection algorithm 194. For example, the system controller 190 sets the supply reservoir 144 to a pressure of about 0 PSI, then using pressure source 166 and vent 180 transitions the pressure of the supply reservoir 144from about 0 PSI to about 1.2 PSI, all the while the volume detection algorithm 194 monitors the pressure sensor 184 and measures the time $t_r$ for the empty supply reservoir 144 to transition between the two pressure values. In one example, the empty supply reservoir 144 has a known volume $V_r$ of about 600 ml and a time $t_r$ of about 6 sec is measured by the volume detection algorithm 194, therefore $K = V_r/t_r =$

600 ml/6 sec or K = about 100 ml/sec. This K value may be logged by the volume detection algorithm 194. (For a some inkjet printing systems, the K value whether determined by operation 716 or by operation 718 should be substantially the same.) The operations may then proceed to operation 720.

[0083] Operations may include determining 718 the value of K using the supply reservoir 114 that contains an unknown ink volume $V_x$, according to Equation 5, which is: $K = V_i/(t_x - t_i)$. $V_i$ is a known volume of ink that is added to the supply reservoir 114, $t_x$ is the time that it takes to transition the supply reservoir 114 having an unknown ink volume from one pressure value to another pressure value, and $t_i$ is the time it takes to transition the supply reservoir 114 from one pressure value to another pressure value after adding the known volume of ink $V_i$ to the supply reservoir 114. For example, the system controller 190 sets the supply reservoir 114 to a pressure of about 0 PSI, then using pressure source 166 and vent 180 transitions the pressure of the supply reservoir 114 from about 0 PSI to about 1.2 PSI, all the while the volume detection algorithm 194 monitors the pressure sensor 184 and measures the time $t_x$ for the supply reservoir 114 having an unknown ink volume $V_x$ to transition between the two pressure values. In some examples, $t_x$ is 2.6 sec. Then a known volume of ink $V_i$ is added to the supply reservoir 114. In additional examples, $V_i$ is 150 ml. Then system the controller 190 sets the supply reservoir 114 to a pressure of about 0 PSI, then using the pressure source 166 and the vent 180 transitions the pressure of the supply reservoir 114 from about 0 PSI to about 1.2 PSI, all the while the volume detection algorithm 194 monitors the pressure sensor 184 and measures the time $t_i$ for the supply reservoir 114 that has both the unknown ink volume $V_x$ plus the known volume of ink $V_i$ to transition between the two pressure values. In some examples, $t_i$ is 1.1 sec. Therefore, $K = V_i/(t_x - t_i)$ = 150 ml/(2.6 sec – 1.1 sec) = 150 ml/1.5 sec or K = about 100 ml/sec. This K value may be logged by the volume detection algorithm 194. (For some inkjet printing systems, the K value whether determined by operations 716 or 718 should be substantially the same.) The operations may proceed to operation 720.

[0084] In some implementations, operations include determining 720 the time to transition the supply reservoir 114 from a first pressure level to a second pressure level by monitoring the supply reservoir pressure sensor 184. The second pressure level must be below a cracking pressure of check valve 142. In some examples, the time $t_x$ that it takes to transition the supply reservoir 114 having an unknown ink volume $V_x$ from, for example, about 0 PSI to about 1.2 PSI is determined using the volume detection algorithm 194, which is monitoring the pressure sensor 184. In particular, the elapsed time is measured between the pressure sensor 184 reading about 0 PSI and the pressure sensor 184 reading about 1.2 PSI. This elapsed time is recorded as the time $t_x$. In some examples, the time $t_x$ is about 2.6 sec. The operations may proceed to operation 722.

[0085] Operations may include determining 722 the air-above-ink volume and the unknown supply reservoir ink volume. The air-above-ink volume $V_a$ is determined according to Equation 3, which is $V_a = K*t_x$; where the K value of operation 716 or 718 and the time $t_x$ of operation 720 is used. In some examples, when K is 100 ml/sec and time $t_x$ is about 2.6 sec, then $V_a$ = 100 ml/sec x 2.6 sec = 260 ml. Subsequently, the unknown reservoir ink volume $V_x$ is determined according to Equation 2, which is $V_x = V_r-V_a$, where $V_r$ is the known empty reservoir volume. In some examples, when the known empty reservoir volume $V_r$ is 600 ml and the air-above-ink volume $V_a$ is 260 ml, then $V_x$ = 600 ml-260 ml = 340 ml. These calculations may be performed using the volume detection algorithm 194. The operations may proceed to operation 724.

[0086] Operations may include determining 724 whether the supply ink volume determined in operation 726 is below a threshold limit. The threshold limit of ink volume for a supply reservoir 114 and associated inkjet printing system 100 is optimized such that sufficient ink volume is maintained in the supply reservoir 114 and primary reservoir 134 to allow uninterrupted ink jetting for the period of time that is required to replenish the supply reservoir. In some examples, the threshold limit of ink volume for a 600 ml supply reservoir 114 is 200 ml. The volume detection algorithm 194 compares the $V_x$ value of operation 722 to the threshold limit value. If $V_x$ is equal to or less than the threshold limit, operations may proceed to operation 726. If $V_x$ is greater than the threshold limit, operations may return to operation 710.

[0087] Operations may include replenishing 726 or prompting replenishment of the ink 122 in the supply reservoir 114 . In some examples, the volume detection algorithm 194 prompts an operator or user of the hot-melt inkjet printing system 100 to load one or more solid blocks of hot-melt ink 122 into the supply reservoir 114. The operations may proceeds to operation 728.

[0088] Operations may include determining 728 whether the supply ink volume has been replenished. For example, in the hot-melt inkjet printing system 100, a sensor may be disposed on the latch of the access door 118 for sensing opening/closing to indicate that a block of hot-melt ink 122 has been added to the supply reservoir 114. If the supply ink volume has been replenished, the operations may return to operation 710, otherwise the operations may return to operation 726.

[0089] Throughout the normal inkjet printing operations and purge operations of the hot-melt inkjet printing system 100, the system controller 190 continuously monitors feedback from the flood ink sensor 186. As long as the temperature of the liquid detector 186 (e.g., flood ink sensor 186, such as a thermistor-type sensor, in the vacuum/pressure line 176 of the primary reservoir 134 of the inkjet printing system 100) remains at an expected level, no action is initiated to clear the vacuum/pressure line 176 of the primary reservoir 134. However, in the event that a circumstance occurs that causes the hot-melt ink 122 to inadvertently splash into the vacuum/pressure line 176, the system controller 190 detects a temperature drop at the flood ink sensor 186. In response, the system controller 190 temporarily interrupts the normal system operations (e.g., interrupts the slight vacuum at the primary reservoir 134) and initiates a recovery cycle. The system controller 190 rapidly deactivates vacuum/pressure sources, such as the pressure source 166 and the vacuum source 170, and/or rapidly applies pressure to the vacuum/pressure line 176 (e.g., via the pressure source 166) to rapidly push the hot-melt ink 122 out of the pathway and back into the rapid heating reservoir 134. Subsequently, normal system operations may resume. In this way, the vacuum/pressure line 176 is protected from clogging, system components, such as the pressure source 166, the vacuum source 170, and the control devices 172, are protected from ink contamination, and system failure is avoided.

[0090] Referring to FIG. 8, a flow chart 800 represents an arrangement of operations of using a melt-on-demand, two-reservoir ink delivery system, such as the ink delivery system 110, in a hot-melt inkjet printing system 100. Operations may include executing 810 normal inkjet printing operations (e.g., as described with reference to FIG. 7) and continuously monitoring 814 the primary ink sensor 154 of the primary reservoir 134. For example, the system controller 190 continuously monitors feedback from the primary ink sensor 154 of the rapid heating reservoir 134.

Operations further include determining 818 whether a low ink level in the primary reservoir 134 is detected (e.g., via the primary ink sensor 154). If yes, operations may include commencing 822 a melt-on-demand cycle. If no, operations include returning to executing 810 normal inkjet printing operations. In commencing 822 a melt-on-demand cycle, the heating function of the supply reservoir 114 is activated to melt hot-melt ink 122. For example, the heater 126 and, optionally, the emersion heater 130 of the supply reservoir 114 are activated to rapidly melt a certain amount (e.g., an amount suitable to satisfy the rapid heating reservoir 134) of hot-melt ink 122 in the supply reservoir 114, which results in a certain amount of hot-melt ink 122 rapidly transitioning from an entirely or partially cold solid state to a hot liquid state. The melting time may be about 10 minutes or less.

[0091] In some implementations, operations further include pumping 826 the liquid hot-melt ink 122 from the supply reservoir 114 to the primary reservoir 134. For example, pressure (e.g., about 6 PSI of pressure) is applied to the supply reservoir 114 via the pressure source 166 and the vacuum/pressure line 174 to pump a quantity of liquid hot-melt ink 122 from the supply reservoir 114 through the fluid line 138 and into the rapid heating reservoir 134, where the liquid hot-melt ink 122 is maintained at an elevated temperature. There may be, for example, about a 3 minute delay before the hot-melt ink 122 exits the supply reservoir 114. Operations may include continuously monitoring 830 the primary ink sensor 154 of the primary reservoir 134. For example, the system controller 190 continuously monitors feedback from primary ink sensor 154 of rapid heating reservoir 134. Operations may include determining 834 whether the ink 122 in the primary reservoir 134 is sufficiently replenished (e.g., via the primary ink sensor 154). If no, operations return to pumping 826 the liquid hot-melt ink 122 from the supply reservoir 114 to the primary reservoir 134. If yes, operations may further include deactivate 838 the heating function of supply reservoir 114 and suspending pumping, thereby ending the melt-on-demand cycle. For example, the heater 126 and, optionally, the emersion heater 130 of the supply reservoir 114 are deactivated and pressure is suspended, thus allowing the hot-melt ink 122 to begin cooling. Operations may return to executing 810 normal inkjet printing operations.

[0092] In some implementations, the melt-on-demand cycle is represented by the combination of operations 818, 822, 826, 830, 834, and 838, the entirety of which may take a few minutes only, such as about 10 minutes or less. Furthermore, the time it takes to perform the melt-on-demand cycle is suitably short to cause no interruption of the normal hot-melt inkjet printing operations.

[0093] In some implementations of the melt-on-demand, two-reservoir ink delivery system, the rapid melt-on-demand cycle maximizes the amount of time that the hot-melt ink 122 in the supply reservoir 114 is held in a cold solid state and minimizes the amount of time that the hot-melt ink 122 is in a hot liquid state. In doing so, inkjet system failures in low-usage hot-melt printing applications are generally minimized or eliminated entirely. Additionally, hot-melt ink degradation in low-usage hot-melt printing applications is generally minimized or eliminated entirely. Conventional hot-melt inkjet printing systems typically store and heat the hot-melt ink remotely and then maintain the hot-melt ink in a heated liquid state until consumed. Furthermore, the effectiveness is prolonged of hot-melt inks that tend to degrade under prolonged high temperature conditions, and the effectiveness is extended of those hot-melt inks that have certain desirable properties, such as improved adhesion, but that tend to degrade under prolonged high temperature conditions. By maximizing the amount of time that the hot-melt ink 122 in the supply reservoir 114 is held in a cold solid state, the opportunity for air to be absorbed into the hot-melt ink 122 when in liquid state may be reduced.

[0094] Referring to FIG. 9, a flow chart 900 represents an arrangement of operations of detecting liquid in air or gas pathways of a hot-melt inkjet printing system 100. Operations include executing 910 normal inkjet printing operations, and monitoring 914, either continuously or poled at intervals, the liquid detector 186 of the pathway of interest. For example, the system controller 190 monitors feedback from the flood ink sensor 186 in the vacuum/pressure line 176 of the rapid heating reservoir 134, either continuously or at certain intervals. Operations further include determining 918 whether fluid is detected in the pathway. For example, determining whether hot-melt ink 122 is detected in the vacuum/pressure line 176 of the rapid heating reservoir 134. If the temperature of flood ink sensor 186 remains at an expected level, no action is initiated to clear the vacuum/pressure line 176 of the rapid heating reservoir 134 and operations return executing 910 normal inkjet printing operations. However, if the system controller 190 reads a temperature drop at the flood ink sensor 186, due to hot-melt ink 122 inadvertently splashing into the vacuum/pressure line 176, operations may further include temporarily interrupting 922 the normal system operations and turning off the vacuum/pressure pumps and/or applying pressure to clear the pathway of interest. For example, the system controller 190 temporarily interrupts the normal printing operations (e.g., interrupts the slight vacuum at the rapid heating reservoir 134) and rapidly deactivates certain pumps, such as the pressure source 166 and the vacuum source 170, and/or rapidly applies pressure to the vacuum/pressure line 176 via the pressure source 166, in order to rapidly push the hot-melt ink 122 out of the vacuum/pressure line 176 and back into the rapid heating reservoir 134. The system controller 190 responds rapidly to clear the vacuum/pressure line 176, preferably, before the hot-melt ink 122 has time to solidify in the pathway. Operations include resuming 926 the normal inkjet printing operations.

[0095] Various implementations of the systems and techniques described here (e.g., the ink volume detector 102, and the system controller 190, the liquid detector 186) can be realized in digital electronic circuitry, integrated circuitry, specially designed ASICs (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations can include implementation in one or more computer programs that are executable and/or interpretable on a programmable system including at least one programmable processor, which may be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device.

[0096] These computer programs (also known as programs, software, software applications or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the terms "machine-readable medium" "computer-readable medium" refers to any computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term "machine-readable signal" refers to any signal used to provide machine instructions and/or data to a programmable processor.

[0097] Embodiments of the subject matter and the functional operations described in this specification can be implemented in digital electronic circuitry, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. Embodiments of the subject matter described in this specification can be implemented as one or more computer program products, i.e., one or more modules of computer program instructions encoded on a computer readable medium for execution by, or to control the operation of, data processing apparatus. The computer readable medium can be a machine-readable storage device, a machine-readable storage substrate, a memory device, a composition of matter effecting a machine-readable propagated signal, or a combination of one or more of them. The term "data processing apparatus" encompasses all apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, or multiple processors or computers. The apparatus can include, in addition to hardware, code that creates an execution environment for the computer program in question, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, or a combination of one or more of them. A propagated signal is an artificially generated signal, e.g., a machine-generated electrical, optical, or electromagnetic signal, that is generated to encode information for transmission to suitable receiver apparatus.

[0098] A computer program (also known as a program, software, software application, script, or code) can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program does not necessarily correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub programs, or portions of code). A computer program can be deployed to be executed on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communication network.

[0099] The processes and logic flows described in this specification can be performed by one or more programmable processors executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit).

[0100] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read only memory or a random access memory or both. The essential elements of a computer are a processor for performing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto optical disks, or optical disks. However, a computer need not have such devices. Moreover, a computer can be embedded in another device, e.g., a mobile telephone, a personal digital assistant (PDA), a mobile audio player, a Global Positioning System (GPS) receiver, to name just a few. Computer readable media suitable for storing computer program instructions and data include all forms of non volatile memory, media and memory devices, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto optical disks; and CD ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic circuitry.

[0101] Embodiments of the subject matter described in this specification can be implemented in a computing system that includes a back end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the subject matter described is this specification, or any combination of one or more such back end, middleware, or front end components. The components of the system can be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network ("LAN") and a wide area network ("WAN"), e.g., the Internet.

[0102] The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[0103] While this specification contains many specifics, these should not be construed as limitations on the scope of the invention or of what may be claimed, but rather as descriptions of features specific to particular embodiments of the invention. Certain features that are described in this specification in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[0104] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0105] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. Accordingly, other implementations are within the scope of the following claims. For example, the actions recited in the claims can be performed in a different order and still achieve desirable results.

WHAT IS CLAIMED IS:

1. A hot-melt inkjet printing system (100) comprising:

a first reservoir (114) for holding hot-melt ink (122);

a first reservoir heater (126, 130) configured to heat the first reservoir (114);

a second reservoir (134, 200) in fluid communication with the first reservoir (114); and

a jetting assembly (146) in fluid communication with the second reservoir (134, 200);

wherein the second reservoir (134, 200) comprises:

a reservoir body (210);

a cavity (212) defined by the reservoir body (210) for holding hot-melt ink (122); and

fins (214) disposed in the cavity (212).

2. The hot-melt inkjet printing system (100) of claim 1, wherein the fins (214) are integral with a bottom surface (213) of the cavity (212) of the reservoir body (210).

3. The hot-melt inkjet printing system (100) of any of the previous claims, wherein the fins (214) are aligned substantially parallel with a longitudinal axis (205) defined by the reservoir body (210).

4. The hot-melt inkjet printing system (100) of any of the previous claims, wherein an operating ink level (F) in the cavity (212) above the fins (214) is substantially equal to a gap distance (G) between the fins (214).

5. The hot-melt inkjet printing system (100) of any of the previous claims, wherein the reservoir body (210) and the fins (214) comprise a thermally conductive material.

6. The hot-melt inkjet printing system (100) of any of the previous claims, further comprising a check valve (142) controlling fluid flow in the fluid communication between the first reservoir (114) and the second reservoir (134, 200).

7. The hot-melt inkjet printing system (100) of any of the previous claims, further comprising an emersion heater (130) coupled to the first reservoir (114).

8. The hot-melt inkjet printing system (100) of any of the previous claims, further comprising a pressure source (166) and/or a vacuum source (170) pneumatically coupled to the first reservoir (114).

9. The hot-melt inkjet printing system (100) of any of the previous claims, further comprising a liquid detector (186) disposed in at least one pathway (174, 176) in fluid communication with one of the reservoirs (114, 134, 200) for detecting liquid ink in the at least one pathway (176).

10. The hot-melt inkjet printing system (100) of claim 9, wherein the liquid detector (186) comprises a temperature sensor.

11. The hot-melt inkjet printing system (100) of claim 9 or claim 10, further comprising:

a pressure source (166) pneumatically coupled to the first reservoir (114);

a vacuum source (170) pneumatically coupled to the first reservoir (114); and

a controller (190) configured to monitor the liquid detector (186), the controller (190) configured to change a pressure of the at least one pathway (174, 176) when liquid ink is detected in the at least one pathway (174, 176).

12. The hot-melt inkjet printing system (100) of any of the previous claims, further comprising a controller (190) configured to monitor an ink level (L) of the second reservoir (134, 200).

13. A method of controlling a hot-melt inkjet printing system (100) comprising:

monitoring an ink level sensor (154) of a first reservoir (134, 200);

determining whether the ink level (L) of the first reservoir (134, 200) is below a threshold level;

heating a second reservoir (114) holding hot-melt ink (122); and delivering melted hot-melt ink (122) from the second reservoir (114) to the first reservoir (134, 200) for replenishing the ink level (L) of the first reservoir (134, 200).

14. The method of claim 13, further comprising:

determining whether with the ink level (L) of the replenished first reservoir (134, 200) is above the threshold level;

discontinuing delivery of melted hot-melt ink (122) from the second reservoir (114) to the first reservoir (134, 200); and

discontinuing the heating of the second reservoir (114).

15. The method of claim 13 or claim 14, further comprising maintaining the hot-melt ink (122) in the first reservoir (134, 200) above a threshold temperature.

16. The method of any of claims 13-15, wherein the first reservoir (134, 200) comprises:

a reservoir body (210);

a cavity (212) defined by the reservoir body (210) for holding hot-melt ink (122); and

fins (214) disposed in the cavity (212).

17. The method of claim 16, wherein the threshold ink level of the first reservoir (134, 200) comprises an ink level (F) above the fins (214) that is substantially equal to a gap distance (G) between the fins (214).

18. The method of any of claims 13-17, further comprising:

monitoring a liquid detector (186) disposed in a pathway (174, 176) in fluid communication with one of the reservoirs (114, 134, 200);

determining whether liquid ink (122) is present in the pathway (174, 176); and

removing the liquid ink (122) from the pathway (174, 176).

19. The method of claim 18, wherein determining whether liquid ink (122) is present in the pathway (174, 176) comprises determining a temperature drop in the pathway (174, 176).

20. The method of claim 18, wherein removing the liquid ink (122) from the pathway (174, 176) comprises changing a pressure of the pathway (174, 176).

21. A hot-melt inkjet printing system (100) comprising:

a first reservoir (114) for holding hot-melt ink (122);

a first reservoir heater (126) configured to heat the first reservoir (114);

a second reservoir (134, 200) in fluid communication with the first reservoir (114);

a jetting assembly (146) in fluid communication with the second reservoir (134, 200); and

a liquid detector (186) disposed in at least one pathway (174, 176) in fluid communication with one of the reservoirs (114, 134, 200) for detecting liquid ink (122) in the at least one pathway (174, 176).

22. The hot-melt inkjet printing system (100) of claim 21, wherein the liquid detector (186) comprises a temperature sensor.

23. The hot-melt inkjet printing system (100) of claim 21 or claim 22, further comprising:

a pressure source (166) pneumatically coupled to the first reservoir (114);

a vacuum source (170) pneumatically coupled to the first reservoir (114); and

a controller (190) configured to monitor the liquid detector (186), the controller (190) configured to change a pressure of the at least one pathway (174, 176) when liquid ink (122) is detected in the at least one pathway (174, 176).

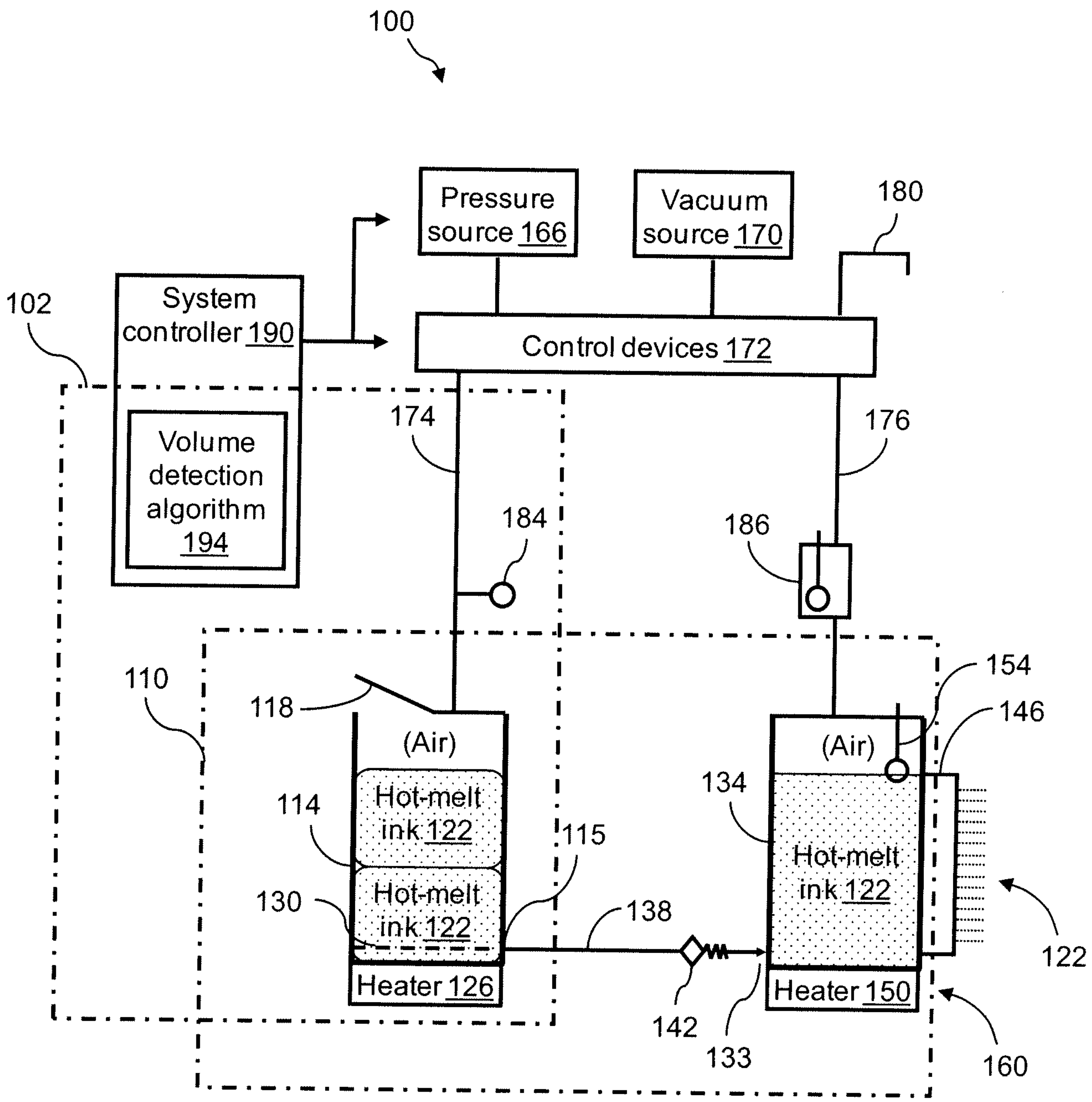
100
Pressure source 166
Vacuum source 170
180
System controller 190
102
Control devices 172
Volume detection algorithm 194
174
176
184
186
110
154
146
118
(Air)
(Air)
134
114
Hot-melt ink 122
Hot-melt ink 122
115
Hot-melt ink 122
130
138
122
Heater 126
Heater 150
142
133
160

FIG. 1

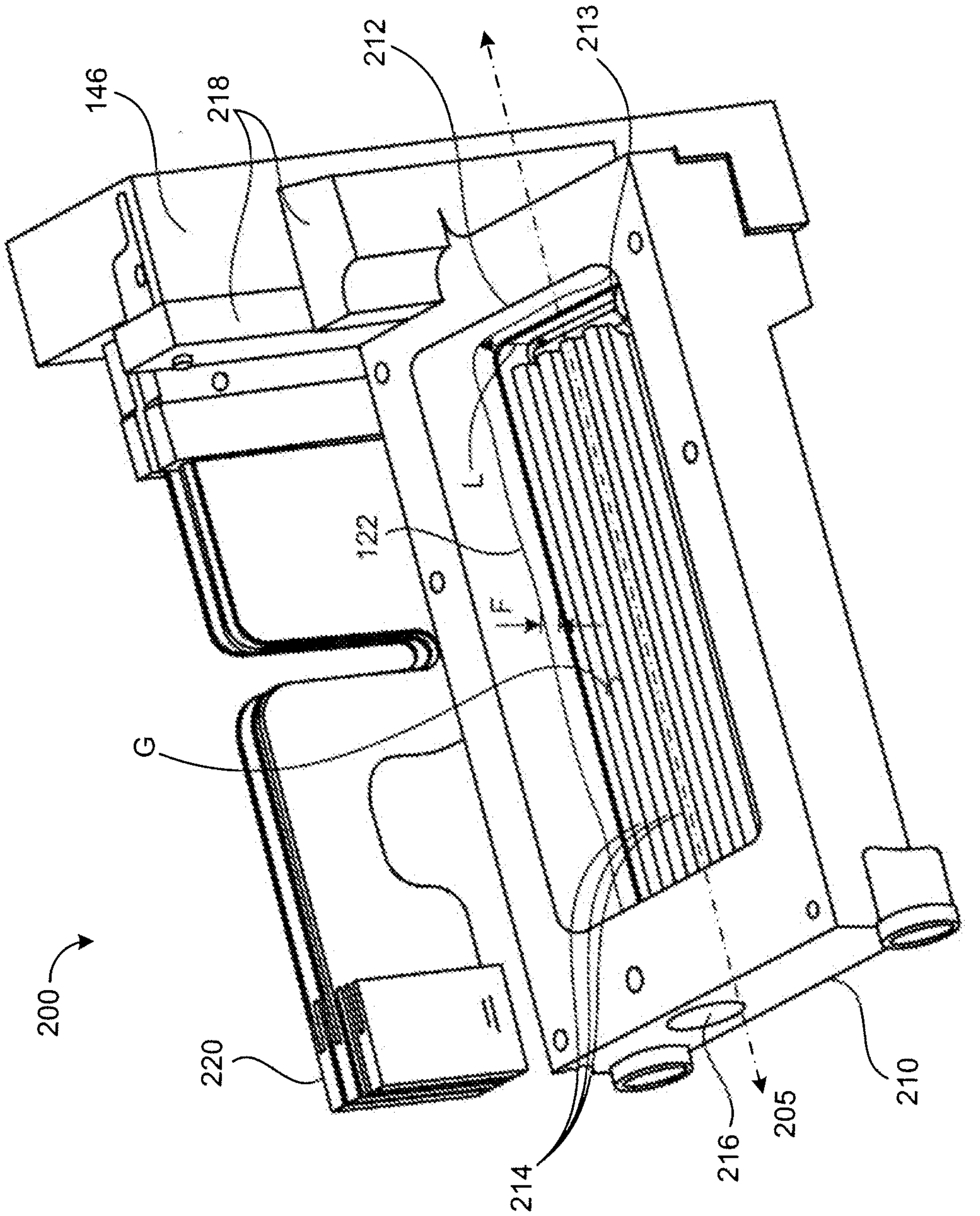


FIG. 2

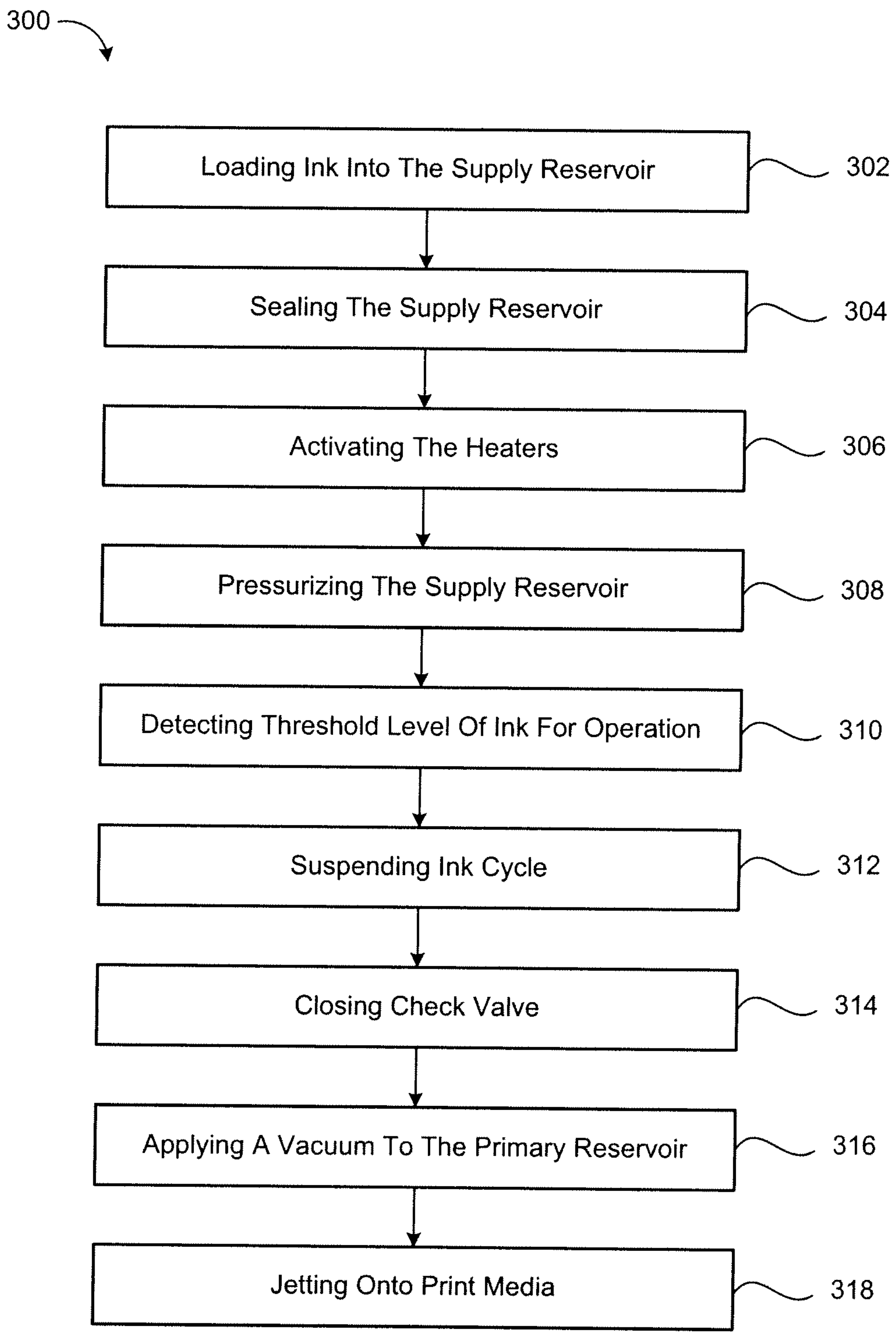
300
Loading Ink Into The Supply Reservoir
302
Sealing The Supply Reservoir
304
Activating The Heaters
306
Pressurizing The Supply Reservoir
308
Detecting Threshold Level Of Ink For Operation
310
Suspending Ink Cycle
312
Closing Check Valve
314
Applying A Vacuum To The Primary Reservoir
316
Jetting Onto Print Media
318

FIG. 3

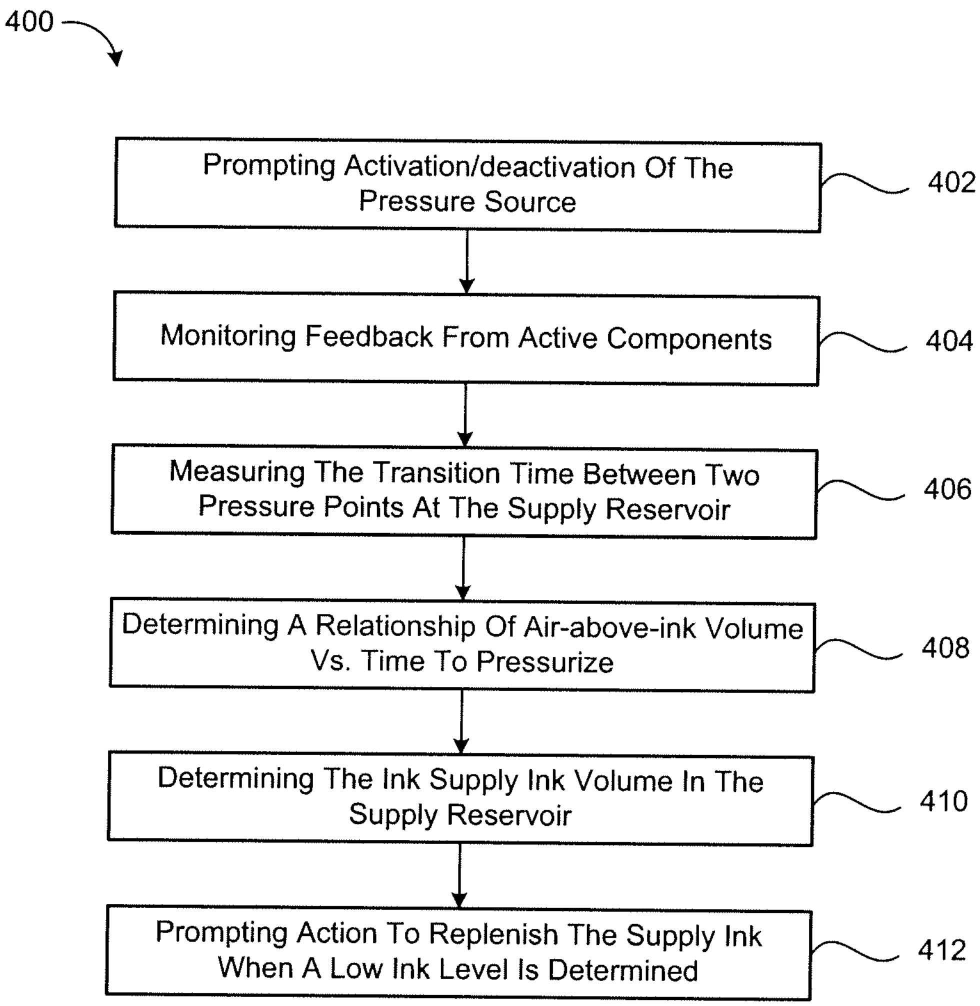
400
Prompting Activation/deactivation Of The Pressure Source
402
Monitoring Feedback From Active Components
404
Measuring The Transition Time Between Two Pressure Points At The Supply Reservoir
406
Determining A Relationship Of Air-above-ink Volume Vs. Time To Pressurize
408
Determining The Ink Supply Ink Volume In The Supply Reservoir
410
Prompting Action To Replenish The Supply Ink When A Low Ink Level Is Determined
412

FIG. 4

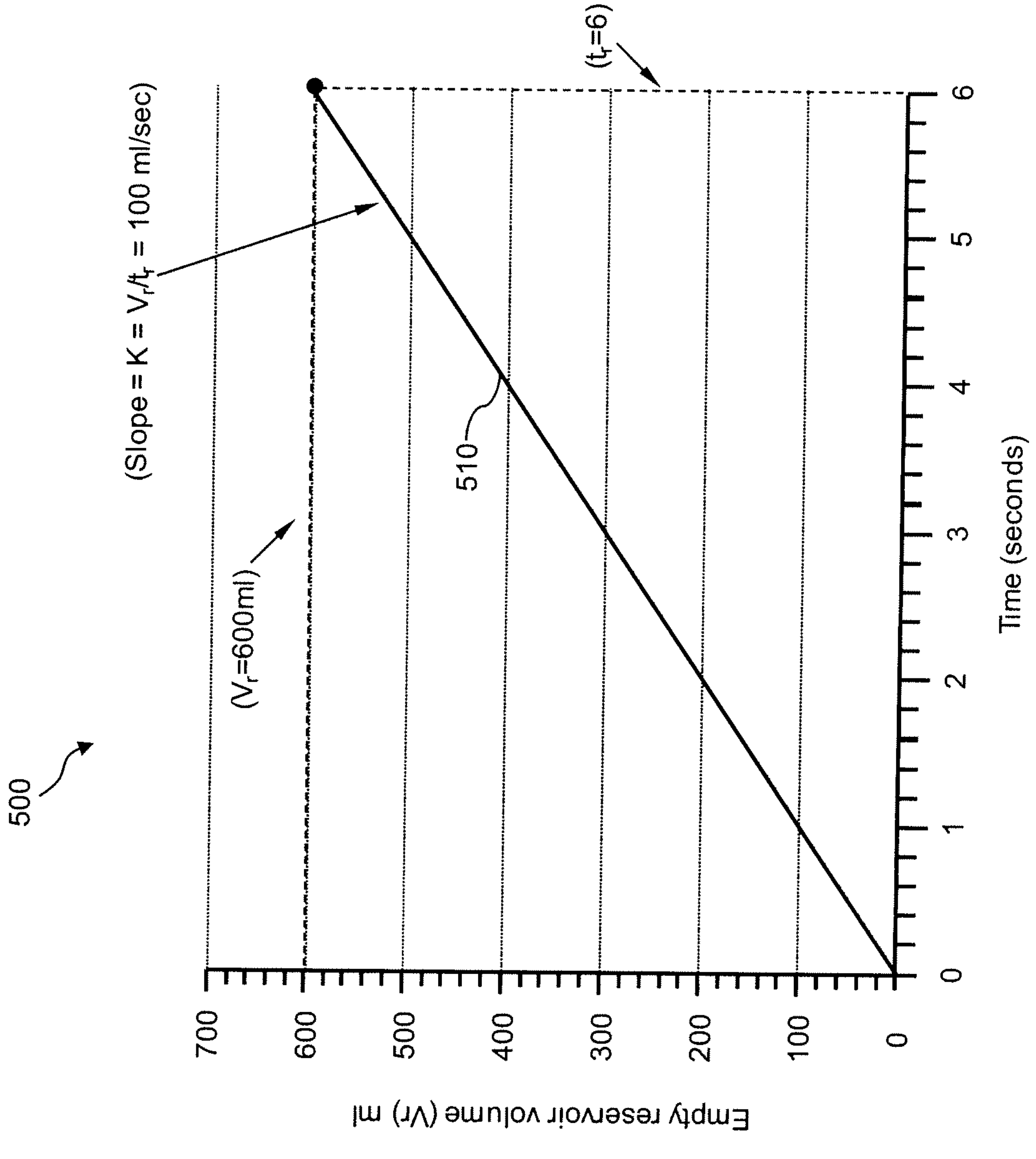
500
(Slope = K = $V_r/t_r$ = 100 ml/sec)
($V_r$=600ml)
($t_r$=6)
510
Empty reservoir volume (Vr) ml
Time (seconds)
0
100
200
300
400
500
600
700
0
1
2
3
4
5
6

FIG. 5

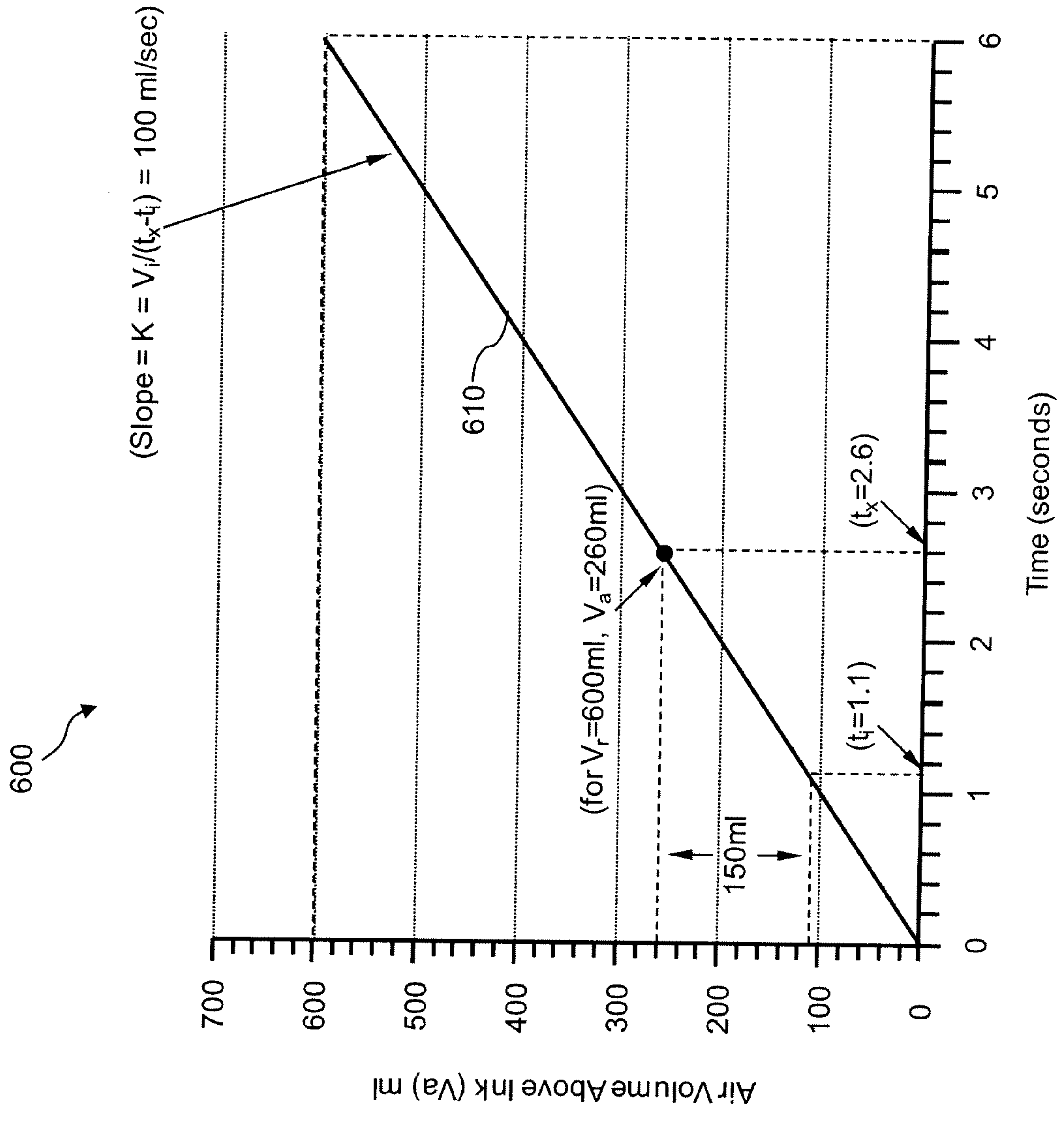
600
(Slope = K = $V_i/(t_x-t_i)$ = 100 ml/sec)
610
(for $V_r$=600ml, $V_a$=260ml)
150ml
($t_i$=1.1)
($t_x$=2.6)
0
100
200
300
400
500
600
700
Air Volume Above Ink (Va) ml
0
1
2
3
4
5
6
Time (seconds)

FIG. 6

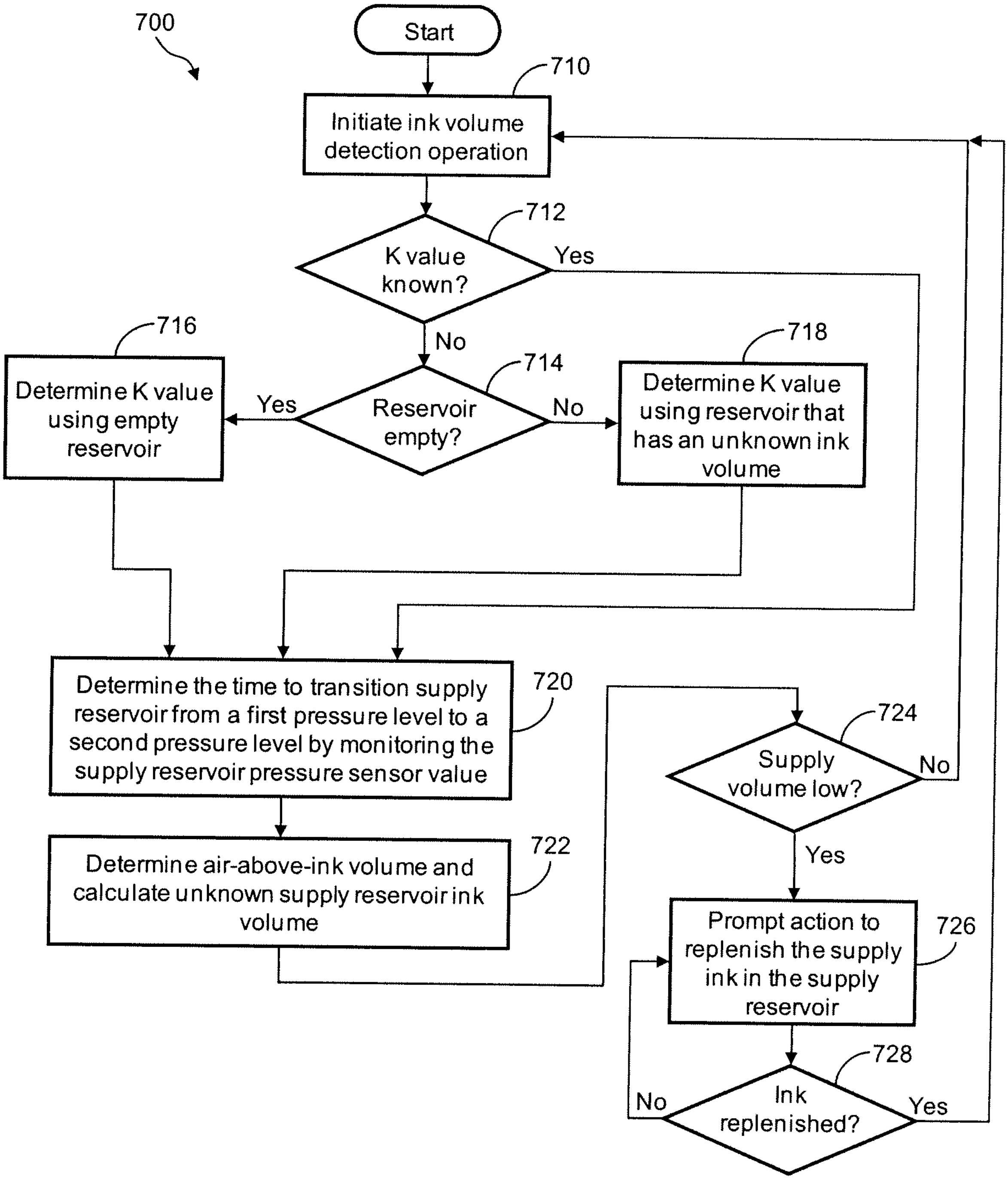
700
Start
710
Initiate ink volume detection operation
712
K value known?
Yes
No
714
Reservoir empty?
Yes
No
716
Determine K value using empty reservoir
718
Determine K value using reservoir that has an unknown ink volume
720
Determine the time to transition supply reservoir from a first pressure level to a second pressure level by monitoring the supply reservoir pressure sensor value
722
Determine air-above-ink volume and calculate unknown supply reservoir ink volume
724
Supply volume low?
No
Yes
726
Prompt action to replenish the supply ink in the supply reservoir
728
Ink replenished?
No
Yes

FIG. 7

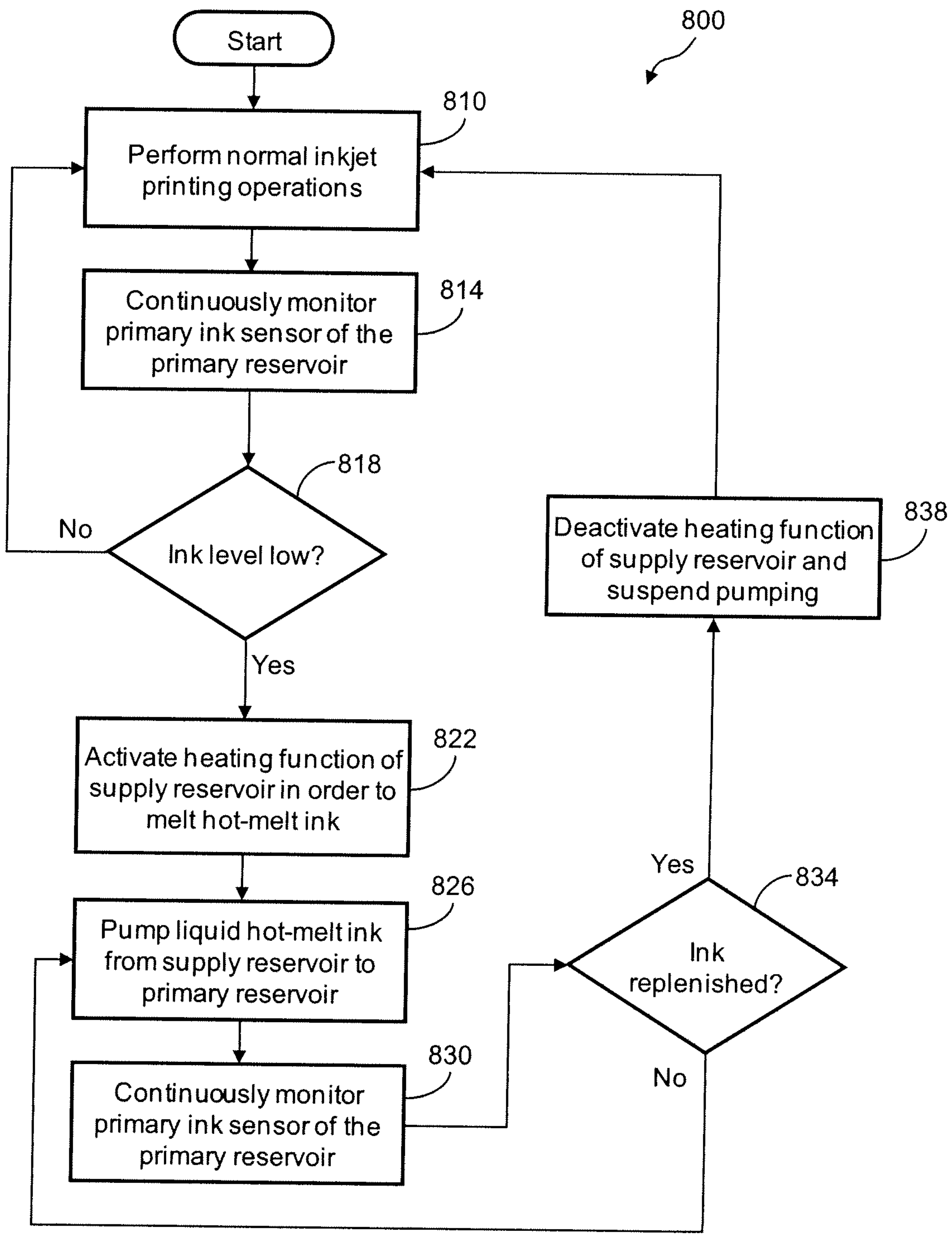
800
Start
Perform normal inkjet printing operations
810
Continuously monitor primary ink sensor of the primary reservoir
814
818
Ink level low?
No
Yes
Activate heating function of supply reservoir in order to melt hot-melt ink
822
Pump liquid hot-melt ink from supply reservoir to primary reservoir
826
Continuously monitor primary ink sensor of the primary reservoir
830
Ink replenished?
834
Yes
No
Deactivate heating function of supply reservoir and suspend pumping
838

FIG. 8

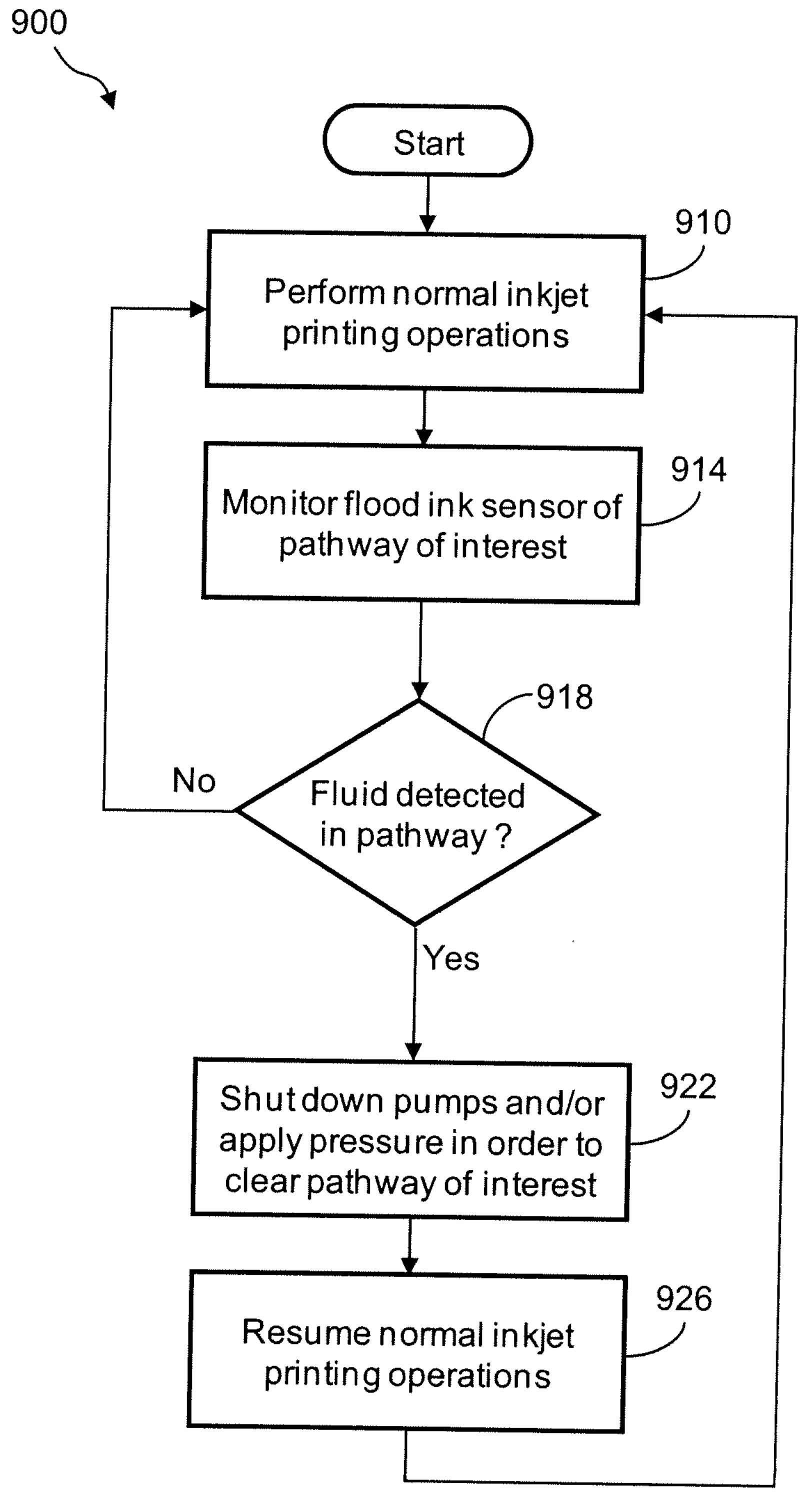
900
Start
910
Perform normal inkjet printing operations
914
Monitor flood ink sensor of pathway of interest
918
Fluid detected in pathway ?
No
Yes
922
Shut down pumps and/or apply pressure in order to clear pathway of interest
926
Resume normal inkjet printing operations

FIG. 9

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/051100

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. B41J2/175

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
B41J G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 4 814 786 A (HOISINGTON PAUL A [US] ET AL) 21 March 1989 (1989-03-21) column 2, line 8 - column 6, line 19 | 1-3,5-8, 12-16 |
| X | US 5 621 444 A (BEESON ROBERT R [US]) 15 April 1997 (1997-04-15) column 1, line 61 - column 5, line 20 | 1,5,7,9, 21 |
| X | US 4 593 292 A (LEWIS ARTHUR M [US]) 3 June 1986 (1986-06-03) column 2, line 10 - column 3, line 10 | 13,15 |
| A | column 3, line 8 - line 10 | 10,22 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 2 November 2009 | 12/11/2009 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Van Oorschot, Hans |

# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
PCT/US2009/051100

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
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| | | | DE | 3884333 | T2 | 28-04-1994 |
| | | | EP | 0313597 | A1 | 03-05-1989 |
| | | | JP | 2500426 | T | 15-02-1990 |
| | | | WO | 8808514 | A1 | 03-11-1988 |
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| US 4593292 | A | 03-06-1986 | CA | 1244716 | A1 | 15-11-1988 |
| | | | DE | 3572622 | D1 | 05-10-1989 |
| | | | EP | 0178880 | A1 | 23-04-1986 |
| | | | JP | 1980459 | C | 17-10-1995 |
| | | | JP | 3056666 | B | 28-08-1991 |
| | | | JP | 61098546 | A | 16-05-1986 |